and on long ocean voyages its effects are felt, not merely in the lessened expenditure of coal, but in the gain in cargo-carrying capacity. Twenty-five years ago an expenditure of from 4 to 6 pounds of coal per indicated horse-power per hour was considered good engineering practice. By the introduction of surface-condensers the expenditure was reduced to about 3 to 4 pounds; by the use of the compound engine with higher steam pressures the expenditure fell to about 2 to 2¾ pounds; and now with triple expansion it has been brought nearly to 1½ pounds, or less than one-third of the rate common a quarter of a century ago. These are results of which marine engineers may be proud, and which make the extended use of steamships certain. Nor is further progress to be doubted. Much remains to be done in improving the marine border, and Mr. Milton's thoughtful paper on the subject will do good. Attention has been so fixed on the economical use of steam in the engines, that the possible gains by improvements on the generators of the steam have been overlooked to some extend. The employment o "forced draught" in the stokeholes is becoming so common, that it was to be expected that a discussion would arise upon it. Mr. Robinson read a paper describing a method by which steam yachts might have the combustion quickened by driving air under pressure into the furnaces, but not closing in the stokeholes as is done in torpedo boats. This paper was not merely interesting in itself, but served the useful purpose of calling forth some valuable statements of experience gained on larger ships. Forced draughts with closed stoke-holes is now becoming a recognised feature in warship design. By these arrangements, involving very moderate additions of weight and cost, the indicated horse-power can be increased by from 50 to 60 per cent. above that obtained with natural draught, and the "forcing" of the combustion can be carried on for four or five hours. A very considerable gain of speed is thus possible for a moderate time, and under ordinary working conditions with low speed, the economical expenditure of fuel is possible. In special types of merchant ships forced draught would also prove of great value; and even in sea-going steamers something of the kind is likely to be done. Trials are already in progress which promise a great economy in the weight and space required for the steam boilers, while preserving economy in coal consumption. A paper by Mr. Linington, of the Admiralty, on the propelling machinery of high-speed ships, gave a considerable amount of information as to recent Admiralty practice; and another paper by Mr. Joy, described a special arrangement of valve gear adapted for quick-running engines. Upon the efficient working of such gear, and the proper distribution of the steam, very much depends when high piston speeds are accepted, and the weight of machinery reduced.

Mr. Thornycroft's name will always be associated with the introduction of the modern torpedo boat, in which quick running engines of remarkable lightness in proportion to their power are fitted. His paper on a special form of screw propeller suitable for vessels of very shallow draught and relatively high speed naturally attracted great attention. The fundamental principle of this propeller is not a novelty: but Mr. Thornycroft has brought to a practically successful form what has been little more than an experiment in the hands of others. The propeller is one which works with a large amount of "slip," but it is associated with a system of fixed "guide-blades" and casings, by means of which the momentum of the water in the propeller race, which would otherwise be wasted, is made to contribute effectively to the forward thrust of the propeller. The net result of the arrangement is that for a given total weight of propelling apparatus a higher speed can be obtained than is possible with any other propeller yet tried in shallow draught vessels.

Mr. Parker, of Lloyd's, read a paper on the use of thick steel plates for boilers carrying high pressures of steam, with special reference to a case of recent occurrence where a plate fractured badly and in a most unexpected manner. This paper gave rise to one of the most lengthy and interesting discussions at the meetings. Steel makers and users of steel mutually benefit by the joint examination of such problems, which will probably become much rarer than they now are as the manufacture advances. The general opinion expressed in the discussion was distinctly in favour of the generally good behaviour of the new material, whose superior strength, ductility and homogeneity make it so formidable a rival to the best classes of iron.

Two papers on riveted joints were well received: the first giving a *résumé* of recent Admiralty experiments on riveted specimens of steel shipwork; and the other dealing with certain points of importance in the riveting of boiler shells.

Amongst the remaining papers, one, dealing with the stowage of steamships, contained a mass of valuable facts. Another paper dealt with the possibility of making such a disposition of the coal bunkers in steamships that the consumption of the coal might not prejudice the stability or render large quantities of ballast necessary. A third was a scientific attempt to lay down rules for competitive yacht-rocking—a hopeless task we fear.

There still remain to be noticed three of the most important papers in which a distinctly scientific method was followed. Undoubtedly the best of these, from the scientific point of view, was that contributed by Mr. Watts, in which he examined into the remarkable effects which free water may produce in checking the rolling motion of even the largest ships. Mr. R. E. Froude assisted greatly in the investigation, and exhibited a model in which the behaviour and influence of the free water were admirably illustrated. It seems obvious that by this means much greater steadiness at sea may be insured than is possible with bilge keels or other appliances of that kind. But there is a need for scientific treatment in order to secure the best steadying effects in a safe and practicable form.

Another excellent paper was that on "A Mechanical Method of Measuring a Vessel's Stability," by Mr. Heek. Here also a model was used, and by a very ingenious device the movements of the centre of buoyancy of the ship represented by the model were accurately and simply determined for all angles of inclination. It is a method which can be used by comparatively unskilled assistants in a drawing office, although its invention is a proof of thorough knowledge of the principles of stability on the part of the inventor. The plan ought to be widely used, and doubtless will be.

Finally, reference must be made to the only paper contributed by a naval officer, Capt. Noel, in which he attempted to lay down rules of general application for measuring the "fighting efficiencies" of war-ships of all classes and sizes, differentiating their values according to the nature of their speeds, manœuvring powers, armaments, protection, seaworthiness, and other qualities. The task is seemingly a hopeless one, and no general rules can apply. At the same time the paper sets out clearly and succinctly the leading characteristics on which fighting efficiency depends, and in that sense will be of service to the Institution.

W. H. W.

THE EGGS OF FISHES[1]

CONSIDERABLE advances within comparatively recent times having been made in regard to our knowledge of the spawning of fishes, and the treatment of

[1] Introductory Lecture delivered to the Class of Natural History in the University of St. Andrews, on November 10, by Prof. McIntosh, LL.D., F.R.S.

their eggs after deposition, I have selected this subject for the introductory lecture, since some opportunities have lately been afforded for its investigation in our own waters. These facilities have occurred at sea in connection with the Trawling Commission, and on land at the Marine Laboratory—now, I am glad to say, established, by the aid of the Scotch Fishery Board, within easy reach of the students of Natural History in this University.

The subject, moreover, is one of general interest, for it is but a short time since works devoted to the history of British fishes were devoid of allusion to any other mode of spawning than that by which the eggs of our marine fishes were deposited on the bottom of the sea. Indeed, it was believed by most naturalists that the latter was the normal mode of deposition. As a consequence, some of the text-books at present in use either follow the latter view, or do not specially allude to the question. Under these circumstances, it is not surprising that the majority of those who have spent their lives from boyhood onward at the pursuit of line-fishing should maintain, even at this moment, that the eggs of all marine fishes are deposited at the bottom of the sea—with a tenacity all the more persistent as several apparent corroborations by experiment (which they had, with praiseworthy interest, made, and which I shall allude to by and by) seemed to justify their opinion.

The eggs of all fishes are produced in the ovaries—symmetrical organs which lie beneath the vertebral column, and which at different periods of the year present various appearances according to the degree of development of the eggs. Thus in the quiescent condition of the organs, as in the case of the green cod before you, their size is insignificant, while the fully-developed ovaries occupy a large space and weigh several pounds. At first the eggs are very small, but they gradually increase in size by imbibing nourishment from the ovarian follicles in which they are placed.

A feature not sufficiently insisted on in our country is the fact that only a portion of the ovary in most marine fishes becomes "ripe" at a given time, the matured eggs passing along the oviduct and escaping externally. This provision appears to be admirably suited for the increase of the fishes, a constant succession of embryos being thus liberated, and time afforded for those of one stage to disappear, as we shall afterwards see, from the surface of the ocean before those of the succeeding take their places. In America this condition has been clearly described in the Report on the cod-fisheries of Cape Ann, by Mr. Earll, for the United States Fish Commission in 1880; but the account does not seem to have come under the notice of Mr. Oldham Chambers, who alluded to the subject a year or two afterwards.[1] Mr. Earll observes that the individuals (*i.e.* the cod) do not deposit all their eggs in a single day or week, but probably continue the operation of spawning over fully two months. The result of this arrangement is that the American cod begin to spawn in September, and some continue as late as June. The cod in our own seas do not follow the same habit, though their spawning-period extends on each side of the beginning of April. In the same way the period during which the eggs of the various kinds of skate are deposited is considerably lengthened.

On the other hand, such marine fishes as the lump-sucker and bimaculated sucker, the salmon, trout, and most freshwater fishes seem to deposit their eggs within the limited period of a day or two, and consequently the development of the masses of eggs in the ovaries is more nearly simultaneous.

The importance of this point in the history of the eggs of fishes will be apparent when it is viewed in connection with a close time in legislation; for while nothing could be more simple than the fixing of such a period in the case of the salmon, which spawns in rivers, it would be very different in the case of such as the cod, sole, and turbot, both on account of the lengthened and diverse periods in each case, and the vastness of the field in which it is to be applied.

In general form the eggs of ordinary fishes are circular. On deposition they are usually invested by a single layer (zona radiata), though in some, as in the herring, there is another, viz. the vitelline membrane, which lies outside the former. The great mass of the egg is formed by the oval spherules of the food-yolk, which are separated by protoplasmic bands. Near one of the poles the protoplasm usually forms a lenticular area, the germinal disk or germinal area, and the smaller yolk-spherules in this region differ in character from those of the general mass of the egg. During development the eggs show partial segmentation, this process being chiefly confined to the germinal area.

While the circular form as just described is characteristic of the eggs of most fishes, we have a few marine types which deviate from the general rule, *e.g.* *Myxine* (glutinous hag), with its ovoid and fringed eggs, the goby, with its fusiform ova, the gar-pike, saury pike and flying-fish, which have long filaments attached to their eggs—probably for the purpose of fixing them to floating structures of any kind. Amongst other interesting types are the large eggs of the stickleback and the salmon-tribe, and the almost microscopic eggs of the eel. The large ova of the salmon and trout are surpassed, however, by those of the Siluroid genus *Arius*—found both in the Old World and the New (Ceylon and Guiana)—the eggs being somewhat larger than a pea (5-10 mm.): but this is not the only remarkable feature in these fishes, for, as Drs. Günther and Wyman and Prof. Turner have shown, the large eggs are carried by the male in his mouth and gill-chamber until hatched, the small and almost granular palatine teeth making this possible, without injury to the ova. He thus acts the part of a dry nurse, as also does the male pipe-fish (*Syngnathus*), and the sea-horse (*Hippocampus*), the eggs being borne by the male in a pouch on the under surface. In another Siluroid fish (*Aspredo*) from Guiana the remarkable exception occurs of a female fish interesting itself in the care of its young. The skin on the under surface becomes soft and spongy, and the eggs, which are deposited on the ground, adhere by simple pressure of the body over them—very much after the arrangement in the Surinam toad. Only one other female fish shares with this one the distinction just noted, viz. *Solenostoma*, an Indian Lophobranch, in which the ventral fins (free in the male) coalesce to form with the integuments a pouch for the reception and hatching of the eggs. The entire group of the sharks and rays (Elasmobranchs), again, is characterised by the peculiar condition of their eggs, which are not only distinguished by their great size, but by the fact that they are either deposited in horny capsules, or retained in the oviduct until hatched. The former takes place in the common rays, certain dog-fishes (*Scyllium*), and sharks (*Cestracion*), and in the curious *Chimæra* and *Callorhynchus;* while the latter, that is the production of living young, occurs in the rest of the sharks and in *Torpedo*.

As already indicated, the prevalent notion amongst the older naturalists was that fishes of all kinds deposited their eggs on the bottom of the sea, and that extensive migrations were made by various kinds for this purpose, the general impression being that the majority proceeded shorewards to deposit their eggs in the shallow water. This impression was probably due to the fact that the salmon, and perhaps the herring, followed this habit, the former proceeding up rivers, and the latter selecting certain suitable banks (often near land) covered with seaweeds and zoophytes, or a bottom composed of stones and gravel. Building their notions on these facts, it was

[1] "Fish and Fishes," Prize Essays, International Fisheries Exhibition, Edinburgh, 1883, p. 187.

assumed by the older observers that all marine fishes followed similar habits. Thus it was supposed that the cod, haddock, whiting, ling, hake, and other fishes frequented certain banks for the purpose of depositing their eggs, and that various flat fishes, such as the larger examples of turbot and sole, came from deep water to shallow water for the same end. Such conjectures, however, were found to deviate very considerably from the actual condition.

Amongst the earliest to notice that the eggs of certain marine fishes floated were the cod-fishermen of the Loffoden Islands, off the coast of Norway. These Norwegians had noticed that what they called the "roe" of the cod-fish floated in the water on the great fishing-banks, and often at certain seasons to such an extent as to make the water thick. Prof. G. O. Sars, Inspector of Fisheries in Norway, to whom this remark was made, supposed that the fishermen had mistaken some of the lower marine animals for the eggs of fishes, for such a feature was in direct opposition to anything he knew of the spawning of fishes. The subject, however, was soon set at rest, for he proceeded in 1864 to the fishing-grounds above-mentioned, viz. off the Loffoden Islands, and captured in the tow-net immense numbers of the eggs of the cod floating at the surface of the sea. Next year, indeed, on a calm day, Prof. Sars found the sea covered with a dense layer of floating spawn, so that with a sufficiently large net he could have taken tons of it. This occurred over a celebrated fishing-ground, on which the cod were present in enormous numbers, so as to form what the fishermen called a "fish mountain." Sars also found that the ova of the haddock floated, and amongst the eggs procured from the surface of the sea were some from which young fishes resembling gurnards emerged, and he correctly concluded that the ova of the gurnard followed the same habit as those of the cod and haddock.

The impetus given to such observations by the energetic action of the United States Fish Commission enabled the Americans to corroborate the discovery of the Norwegians in regard to the floating of the ova of the cod, which lately have been artificially hatched on a somewhat extensive scale on their coasts. The labours of the distinguished Prof. Alex. Agassiz in the same country have further added to our knowledge of floating eggs, so that the number of fishes in which this occurs is considerable. Thus the majority of the American flounders, certain kinds of wrasses (*Ctenolabrus*), a species of sparling (*Osmerus*), several species of cottus, cod, haddock, gurnard, shad, mackerel, and Spanish mackerel, a kind of dory (*Zeus*), and the frog-fish are amongst those which have floating eggs. The late Dr. Malm of Gothenburg further increased the list by discovering that the eggs of the plaice were similarly buoyant; and G. Brook has recently added to this category the eggs of the lesser weever. The very great influence which this floating of the tiny eggs exercises on the multiplication of the food fishes will be apparent as we proceed.

On the other hand, most freshwater fishes (except the shad) deposit their eggs on the bottom like the salmon, or on water-plants, like the carp and pike; while other marine species, such as the herring, sprat, lump-sucker, and bimaculated sucker, follow a similar method. The number of marine fishes which are supposed to deposit their eggs on the sea-bed is yearly diminishing, while the ranks of those in which the ripe eggs are found to float correspondingly increases.

To come now to our own shores, and to confine our remarks to what is really the most important group of fishes, viz. the food-fishes, we find that early in spring the surface of the sea over the great fishing-banks, such as Smith Bank, off the north-east of Scotland (Caithness), presents vast numbers of floating eggs of food-fishes, together with multitudes of the very young fishes provided with a yolk-sac exhibiting various degrees of absorption. Some of the ova (*e.g.* those of the haddock and gurnard) are larger than those of the cod, but they are few in number; while a fourth kind are smaller than any yet mentioned. When placed in a vessel of sea-water the eggs persistently float on its surface, descending but a very little when the jar is rudely shaken. Even after a protracted journey only the dead eggs roll on the bottom of the vessel. All the floating eggs are living. Moreover, the eggs were removed from the cod itself, and carried from Smith Bank to the Marine Laboratory at the harbour. On arrival, these floated at the surface of the vessel. On transferring them to a larger jar and turning on a tap of sea-water, a great change occurred. The ova in a few minutes lay on the bottom. Microscopic examination subsequently showed that the edge of the germinal area was disintegrating—free protoplasmic processes and separate cells occurring all round. The cause of this sudden change was doubtless the impurity of the water (for the proper apparatus had not yet been fitted up), the metallic pipe (block-tin) containing an opaque whitish deposit which speedily killed the ova. The addition of methylated spirit in the same way sends all the eggs and embryos to the bottom. Sars, indeed, mentions that if the eggs of the cod are placed in fresh water they sink, and never rise again. They are killed—just as a newly-hatched salmon is killed—though somewhat more slowly, by immersion in sea-water. Sars thinks that even a fall of rain might affect the floating of the ova in the sea, but this is unlikely.

More than once the eggs of the haddock and other fishes have been brought under notice as lying on the bottom of a vessel, and therefore held as proving that the ova did not float. But in every case such eggs were found to be dead or dying, unripe, or not even fertilised. If in removing the eggs from a fish, too much pressure is applied, unripe eggs escape. Such either sink or float ambiguously, according to the stage of development. Unless this fact is borne in mind, disappointment naturally occurs, especially to one who has triumphantly carried such eggs from deep-sea fishing to vindicate statements that have been impugned. No one ever asserted that dead eggs floated. It is the ripe and living eggs that are so buoyant.

In the Marine Laboratory it has happened that some living ova of the cod rolled on the bottom of the vessel, but this was clearly due to the attachment of fine particles of mud and sand which had gained admission from imperfections in the temporary apparatus, and which surely and speedily in every case proved fatal to the embryo.

The ova and embryos brought from the surface of the sea are comparatively hardy, even though kept for ten days without renewal of the sea-water. The lively little cod, about 5 mm. in length, with their characteristic black pigment-patches, swam actively at the surface of the water, darting hither and thither when interfered with, while a stratum of the dead lay at the bottom. The water may even be somewhat milky and the odour characteristic, and yet the embryos survive—until, as Sars also found, the yolk-sac, which supplies them with nourishment, is absorbed.

The difference between the larval cod and the young salmon just hatched is striking. The former (that is, the young cod) is in a very rudimentary condition, not only in size, but in structure. For instance, the heart pulsates, but, as my colleague, Prof. Pettigrew, observed, there is no visible blood and no blood-vessels. Those, therefore, who say that the heart in animals contracts from the stimulus of its living blood, would here find little support. On the other hand, the newly-hatched salmon has attained great complexity; indeed, several days may be spent in delineating its elaborate blood-vessels alone.

(*To be continued.*)